E/CONF.39/A/29
28 Sept. 1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.1

Netherlands

# MAPPING AND SURVEYING PRACTICES ADAPTED TO USE IN LESS DEVELOPED AREAS

By Pof. Dr. W. SCHERMERHORN,
Dean of the International Training Centre
for Aerial Survey, ITC,
Delft, Netherlands

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

## NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

# A.1 - MAPPING AND SURVEYING PRACTICES ADAPTED TO USE IN LESS DEVELOPED AREAS

PROF. Dr. W. SCHERMERHORN

Dean of the International Training Centre for Aerial Survey

(I.T.C.), Delft - Netherlands

## 1. Introduction.

Nowadays the production of maps in less developed as well as in industrialized countries is based on the use of airphotographs. Consequently this paper will deal only with photogrammetric methods. The possible speed of production of maps and especially the use which can be made of the photograph as such with its abundance of information make that aerial survey becomes an indispensable tool for the execution of development programs.

Technical services when carrying out for instance engineering or agricultural projects need maps of different scale and precision . The cost of surveys in general represent only a very small percentage of the execution of such projects. There are many examples of waste of money caused by insufficient knowledge of the data which influence the project or its execution. Unfortunately administrative authorities too often consider the cost of surveys as a kind of non-productive expense, which must be reduced as much as possible. This is in particular true for general topographic maps of the country. These maps, originally surveyed in European countries for military purposes, are playing at present a dominant role in civil administration and technical services. Their scales must be adapted to the stage of development of a country and should not be larger than needed in the next 10 years, knowing that the larger the scale, the shorter the interval for resurveying in order to keep the map up to date.

These topographic maps are not only necessary to represent the geography of the country for a wide variety of purposes, but they are also the basis for topical maps of different character, such as geological, soils- and vegetation maps (see par. 6).

A very special service using maps is that for land registration (cadastral administration). Although many cadastral authorities are still hesitating about the application of photogrammetry to cadastral surveys we will show in par. 5 that airphotography can be not only a great help, but even the only tool which enables the responsible authorities in development countries to establish a reliable cadastral administration within a reasonable time.

All photogrammetrically produced maps others than topical maps can be divided into three groups depending on the proportion between the scale of photography and that of the map.

a. geographical maps 1:100,000 to 1:250,000
   enlargement 1:0,8 to 1:0,2

b. topographical maps 1:10,000 to 1:50,000
enlargement 1:4 to 1:0,8

c. technical and cadastral maps 1:1000 to 1:5000
enlargement 1:8 to 1:3.

This division into groups is based on the difference between graphical photogrammetric procedures for different values of the enlargement from photograph to map. Assuming a standard deviation (s.d.) of 160 micron in the manuscript (before reproduction) the s.d. in the position of a point in the photograph can for each of the three groups be between:

a. 200 and 800 microns
b. 40 and 200 microns
c. 20 and 50 microns

This shows that the requirements of precision for the plotting instruments and for the coordinates of passpoints are so different, that different procedures are justified.

Besides the graphical methods also numerical methods using comparators and digital computors are recently being applied to high precision problems such as cadastral surveys where the tolerance for the s.d. is 20 micron or less. In paragraph 7 : "Modern tools in less developed areas" the consequences of such methods will be discussed.

Par. 2. Determination of ground control points by airsurvey methods with a minimum of ground survey.

Almost everywhere field work is more expensive than office work and takes more time for comparable results. The consequence is that we find a continuous effort to replace ground survey needed for the determination of the necessary control in each photograph by other methods such as:

a. the classical aerial triangulation carried out either in universal plotting machines or in stereocomparators where highspeed computors and programmes are available;
b. the use of special equipment in the plane and in some cases also on the ground for the determination of the position of the exposure in space and of the inclination of the optical axis of the camera;
c. A combination of the methods a) and b).

Especially this combination considerably reduces the necessary ground survey, even for medium scale topographic surveys.
In the following part of this paragraph some characteristics of each of these methods is described and their application will be treated in paragraphs 3, 4 and 5.

a). Aerial triangulation.

When working in two shifts of 7 hours each the yearly triangulation capacity of one universal plotting machine with 260 working days lies between 2500 and 3000 pairs. In the stereocomparator the capacity will be between 5000 and 6000 pairs. To this must be added, however, the cost of computation of strip coordinates from plate coordinates. The cost of this will be, in a computor of moderate capacity for the same 6000 pairs which can be produced by the analogue plotter in about 30.000 minutes of $ 0,45 = 13.500.- . Whether the analytical method will be more favourable than the classical method depends therefore on the level of the wages and amortization of a second universal plotter with two operators who would raise the production to the same 6000 pairs. Assuming the amortization of the stereocomparator 1,5 x as high as that of the universal plotter there remain about $ 3500.- for the amortization of the 2nd plotter. This amount leaves for the two operators $ 10.000.- which in many countries will be sufficient. This computation shows that there is not much difference in cost between

the two methods. Therefore for less developed areas where the use of sensitive equipment is anyhow risky, we recommend for aerial triangulation the application of the classical method. This is especially valid for those countries where the number of pairs to be measured is smaller than 3000 per year and the high cost of the comparator can be amortized only over half its full capacity. Yet this instrument cannot, like a universal plotter. be used also for other purposes than aerial triangulation.

There are several survey problems where the heights are either not needed (cadastral maps) or where the requirements are out of proportion to those for planimetry and consequently only ground levelling can do (irrigation etc.). Then the planimetry can be determined by means of the well known slotted templet method if low absolute precision is sufficient. The use of the numerical radial triangulator is a cheap method which gives a high precision specially if the photographs are taken with a camera in a stabilized mount*(1).

The cost of a precision radial triangulator lies between 12 and 15% of that of a universal plotter and the time for observation is 50 to 60% of that needed for measurement of a pair in such a plotter assuming no more than the normal 9 points in each model. A larger number of points per pair decreases the difference in time in favour of the universal plotter. A disadvantage is that so far no mechanical or electronic registration of the readings is available. For adjustment of the rhomboids and computation of strip coordinates $\frac{1}{2}$ hour per pair more is needed than for the strip coordinates from a triangulation in space in a universal plotter. An easier and faster method for this, however, is developed by F. E. Ackermann*(2).

One of the major problems in aerial triangulation in common to each of the three methods mentioned before, is the adjustment of the observations. There exist several methods for the computation of strips. A usual method is to have full ground control of a pair at one end and two points at the other end and in the middle of the strip.

The graphical method of adjustment, called after Zarzycki, derives correction graphs for X, Y and Z-coordinates from the discrepancies in these known points. The same method can be applied numerically in case an electronic computer is available. In that case, however, the least square adjustment method for heights and planimetry with arbitrary positions of the control points as published by Ackermann*(3) is to be preferred.

It is obvious, that all separate adjustments of the strips of a block, each neglecting the many conditions for equal coordinates of the common points, require more ground control than a method of block adjustment which takes these conditions into account. Consequently this block adjustment is at present one of the major problems in photogrammetry. The difficulty is that the adjustment of a block of 10 strips of 20 models requires the solving of $10 \times 20 \times 4 = 800$ normal equations for planimetry only. This requires either the combination of a considerable number of pairs to units, which makes it to an iteration procedure, or a very powerful computer. At present research is carried out in both directions but for less developed areas none of the two can be recommended. Already the small number of blocks which must be adjusted per year does not justify participation in these experiments.


*(1) Van der Weele, A. J. - The precision of Radial Triangulation.
I. T. C. Publications, A9, 1962, Delft.

(2) Ackermann, F. E. - On the adjustment of rhomboids in radial triangulation.
Photogrammetria 1959-60 p. 81-89, Argus, Amsterdam.

(3) Ackermann, F. E. - A procedure for analytical strip adjustment.
I. T. C. Publications, A17, 1962, Delft.

Several mechanical methods of adjustment of blocks are proposed which partly found application. The socalled stereotemplet method*(4) which is popular in the USA needs orientation of the pairs and elimination of relief displacement. It is an improved slotted templet method which yields planimetric coordinates with a precision which depends largely on the scale of the templets.

Another method was developed in Delft*(5). Square sections consisting of a number of models e.g. 3 x 6 = 18 models are formed. Two templets are made of each of these sections at the scale of the map and a kind of stereo-templet triangulation is carried out.

This method was a forerunner of and was surpassed by Dr. Jerie's Analogue Computer developed in the I.T.C. after 1956. Stimulated by the method of Massus d'Autume for the adjustment of heights at the Institut Géographique National de Paris*(6), Dr. Jerie of the Delft ITC in 1956 started with efforts which in 1957 resulted in the design of his analogue computer*(7). With this equipment a least square adjustment of a block can be carried out separately for planimetry and for height. The basic difference with Massu d'Autumes method for height is that Jerie brought into his device the possibility to have residual errors.
No real least square adjustment is possible without the realisation of residual errors. The same was necessary for the adjustment of planimetric coordinates. This requirement was fulfilled in both cases by the use of adequate springs. The basic principle for the adjustment of the planimetry is furthermore the introduction of the discrepancies in the tiepoints between the four surrounding models on a much larger scale than that of the templets, representing the planimetric position. This fact, combined with a fast iteration procedure results in an adjustment system which gives about the same precision as an entirely analytical solution with several hundreds of linear normal equations.

Its advantages are the following:

a) Personnel with only technicians education can carry out the adjustment with the use of this simple equipment and a desk computer.
b) For blocks of 12 strips of 24 models each the necessary ground control for planimetry is 4 points at the corners and 1 point in the middle of each edge of the square block and for height three traverses of height surveys at the ends and in the middle of the strips.
c) Instead of 2 pairs, for surveys of less precision sections can consist of 2 x 4 or 3 x 6 pairs in order to master larger blocks with the same equipment at the cost of a somewhat reduced but still sufficient precision.
d) The time required for the adjustment of planimetry and height by experienced operators using sections of two models is between 2 and 2,5 hour per model.
e) With the use of good observations of the models carried out in universal precision plotters a s.d. in the planimetric position of between 0,02 and 0,04 mm in the plane of the negative is to be expected almost regardless of the scale of photography. This value for the relative errors (discrepancies in the tiepoints) is about half the value of the absolute error. The s.d. of the absolute values of heights is then between 0,025% and 0,035% of the flying height during exposure*(8).


*(4) Scher, Martin B. - Stereotemplet triangulation. Photogrammetric Engineering 1955, p. 655 - 664.

(5) Van der Weele, A.J. - Rational adjustment of blocks in Aerial Triangulation. Photogrammetria 1955-56, p. 306-310, Argus, Amsterdam.

(6) I.G.N. L'aerotriangulation spatiale à l'Institut Géographique National. Communication N. 3: Sur un nouveau procédé de compensation des cheminement photogrammétriques. International Archives of Photogrammetry Vol. XI, Argus, Amsterdam.

(7) Jerie, H.G. - Block adjustment by means of analogue computers. Photogrammetria 1957-58, p. 161 - 176.

(8) Waldhäusl, P. - Height adjustment by the ITC-Jerie method. Photogrammetria 1959-60, p. 29-37, Argus, Amsterdam.

Consequently it is not surprising that for the solution of the problem of correct block adjustment with economizing of ground survey many of the less developed countries use this analogue computer.

Another important problem regarding the computation and adjustment is how to deal with the so-called auxiliary data obtained during exposure such as APR tilt and tip from solar camera or horizon camera etc. How old the use of horizon camera and statoscope may be the method which gives the maximum benefit of these data is still a subject of theoretical and practical research.

Par. 3. Production of geographical and reconnaissance maps 1:100,000 to 1:250,000.

a). General.

There are still considerable parts of the world which are entirely unmapped or which are covered only by classical reconnaissance maps compiled from route surveys of travellers. Such maps have a low absolute precision and the relative accuracy is not homogeneous. The first step to improve existing maps is the use of airphotographs in order to obtain topographic details in areas where the traveller has never passed.

A better product, however, is obtained by starting the construction of a new map from scratch applying the most modern methods. Even then different stages of perfection can be reached. The first possibility is to produce smallscale geographical maps without any representation of height. A second step is to derive from the air photographs the land forms and represent these either by form lines or by shading. If also the planimetry has a very poor precision, a coordinate grid on the map will perhaps be indicated in such a way that this becomes evident.

There are cases where at present photogrammetry makes it possible to produce geographical maps in a scale 1:250,000 better and faster/by means of compilation from existing maps. In particular the high altitude photography, taken with modern lenses in scales 1:100,000 and smaller, in combination with control derived from existing larger scale maps, enables the /than service to produce a geographical map which is up-to-date, also of those areas where the medium scale topographic maps are not complete or out-of-date. This development makes the production of geographical maps by photogrammetric procedures, independent from existing maps, more and more important.

b). Photography.

By using the modern super wide angle camera photography becomes possible in the scales between 1:70,000 and 1:100,000 with the use of normal airplanes. These scales are smaller than the usual 1:50,000 made with 6" cameras, but are entirely sufficient.

It is strongly recommended to use a stabilized mount. If this is impossible other tools for the determination of the inclination of the optical axis (horizon camera or solar periscope) can be used. Furthermore, this kind of survey should no more be carried out without APR as will be explained in 3 c.

In areas where reconnaissance surveys of natural resources must be carried out with the use of these small scale photographs it is recommended to take photographs at the same time with a second camera having a focal distance of 12". This strip in the scale of about 1:30,000, although only covering isolated small strips, can be used as a key for the interpretation of the photographs 1:100,000.

c). Control.

Control for planimetry and for height are different problems, as for these surveys no aerial triangulation in space will be necessary if certain precautions are taken.

The planimetric control can be obtained from a combination of slotted templet and block adjustment with analogue or electronic computer. For the map 1:250,000 with photography 1:80,000 blocks of 30 strips of 60 models each can be mastered in this way. Such a block is 400 x 400 km and no more groundsurvey for planimetry is required than a number of 8 astrofixes around the edges of the block. These astrofixes are at such long distances (150 à 200 km) that the deviations of the plumbline will do not much harm to the relative precision. Tellurometer traverses around the block are even better. In the centre of the block no planimetric control points are needed.

The control for height can be derived from the combination of APR and camera orientation equipment (horizon camera etc.). For maps in the scale 1:100,000 with contours of 100 ft. the APR can provide us with a satisfactory precision of height in the flightline and also of the inclination of the airbase. For the determination of the tilt perpendicular to the flightline the horizon camera is the cheapest solution (after the solar periscope). The stabilization of the camera mount which can give the same precision as these two, is still too expensive and that which is good enough to improve for instance the slotted templet, is not sufficient for this purpose. Another method is to fly cross-strips at regular, rather short mutual distances or to fly low APR strips in the lateral overlap of the photographic strips. This method, too, is more expensive than the use of the said camera orientation equipment. Regarding ground control for height it is sufficient to determine a number of points in the area by precise aneroid observations to check the APR regularly during its flight.

One of the important consequences of this photogrammetric method is that large areas can be mapped without the execution of a time consuming and costly previous primary geodetic triangulation.

Whether other expensive methods should be applied to the survey of geographical maps in less developed areas is doubtful. After World War II electronic methods such as Shoran, Hiran, Decca were used to determine a primary network of points by line-crossing and trilateration (Canada). By the same methods also planimetric coordinates can be obtained of each exposure of a strip of airphotographs. This method was applied to some large projects carried out for the account of US authorities. Compared to the methods as described in par. 2, this method is too expensive and is at present abandoned in those cases where economic considerations are preponderate and where it is preferred to have the survey done by the national manpower of less developed countries.

d). Plotting of the manuscript.

Regarding methods and instruments a wide variety is in use and more research should be carried out with respect to the economy. Very few figures about time of production of these maps have been published and due to the great difference in the type of terrain, individual figures have not much statistical value. The scale of the manuscript is normally twice as large as that of the published map which simplifies the task of the draftsman.
For the method of plotting one must distinguish between real topographic maps and maps with planimetry only. For the latter tracing of the rectified negative is recommended. If the manuscript scale is about the same as that of the photographs a sketchmaster can be used as long as the terrain is only smoothly roling. For plotting of planimetry of terrain with greater difference in altitude, a radial line plotter can render good services. With all these instruments four controlpoints in each pair are required for easy and reliable work.

In case contours must be plotted we recommend the use of so-called third order instruments, such as Drobychew topographic stereometer, Stereotope, Santoni Stereomicrometer or the French Stereoflexe. For these instruments we need in general known height and planimetry of 4 controlpoints in the corners of each model. If aerial triangulation was carried out, these data will be available. Since we however explained that surveys for these maps do not need this in case APR and camera orientation equipment (horizon camera etc.) are used it will then be necessary to develop a system which allows to impose those data directly to these instruments.

The next step, especially preferable for the plotting of maps in the scale 1:100,000, would be the use of the topographic stereoplotters such as Wild Aviographs, Kern PG2, Poivilliers Stereotopographe D and Santoni Stereosimplex II. Whether these are preferable to third-order instruments is more a problem of capital investment than of efficiency. It is not unlikely that these instruments, in particular, if the absolute orientation is known from camera orientation equipment, will show a productivity which compensates for the difference in investment compared to that of third-order plotters.

In case multiplex- or Kelsh-type instruments are used these will show such a large scale of the model that for a map 1:250,000 and even 1:100,000 a strong reduction must be applied. These instruments are less suitable for this kind of plotting than the 3rd order instruments and the cost per hour with one operator is not much less than of the topographic plotters.

Par. 4. Production of topographic maps in the scales between 1:10,000 and 1:50,000.

a). Photography.

The decisive factors effecting the scale of photography are the following:

1. The precision of the planimetry as derived from the errors in the ground control, aerial triangulation and the restitution of each single photograph.
2. The smallest possible contour line interval determined by the same elements.
3. The possibility of distinguishing the necessary topographic detail in the stereoscopic model with the use of available plotting instruments.

It depends on the type of terrain (density of details, contour line interval etc.) and the method of determination of control points which factor is decisive. For maps with contour line interval of 10 m and smaller it will be this value. Since especially in less developed areas aerial triangulation will always be applied to the production of these maps we know that the average standard deviation (s.d.) of arbitrary points of a model 1,2 times that of the control points. This gives for first class quality 1,2 x 0,03% H for height and 45 micron for planimetry. Assuming 150 micron for the s.d. in the position of a point in the manuscript this gives a possible ratio of scales between photograph and map of 1:3. For a map 1:25,000 this would allow a scale of photography 1:75,000 with a flying height H = 11.500 m (using a 15 cm wide angle camera). With these photographs the precision of height would be 0,036 % of H = 4 m. This makes it possible to plot with a contour line interval of 20 m or 50 ft, independent of the scale of the map. This example shows that for an interval of 10 m H must be 5500 m. In cases where the scale of the photographs need not to be large, the use of the super wide angle camera can be useful, which from 5500 m gives then photographs 1:62,500.

Another conclusion of this example is that the C-factor in both cases needs not to be better than 550 and that from this viewpoint precision plotters are not required. This is due to the errors in height introduced by the aerial triangulation. It may be, however, that the many small planimetric details to be plotted justify the use of precision or topographic plotters not because of their better C-factor, but because of the better images they present to the operator.

As a result of the various considerations of which that mentioned above is an example, we find a wide variety of scales.

| Scale of the map | scale of photography. |
|---|---|
| 1:10,000 | 1:10,000 to 1:40,000 |
| 1:25,000 | 1:20,000 to 1:40,000 |
| 1:50,000 | 1:30,000 to 1:70,000 |

There exists at present a fully justified tendency to apply the smallest possible scale of photography. This is especially important to less developed areas with a sparce network of ground control, aerial triangulation and orientation of the models in a plotter is proportional to the number of pairs. Reducing the scale in the proportion 1:n, the number of photographs is reduced $1:n^2$.

b). Control points.

Specially in less developed countries this will be a problem of aerial triangulation as discussed in Par. 2.

Here we stress again the importance of the use of APR and other auxiliary equipment with the photography.
Another important possibility to reduce the cost of aerial triangulation is a combination of a super wide angle and a wide angle camera in the same airplane. On the small scale super wide angle photographs, taken each second strip, the control points necessary for plotting the wide angle photographs are transferred stereoscopically. The aerial triangulation is then carried out with the super wide angle photographs only.

c). Plotting of the manuscript.

For flat terrain the rectifying procedure is recommended with direct tracing of rectified diapositives on a light table. For densely populated areas it is recommended to use, although no contours are needed, one of the stereoscopic 3rd order instruments. These are mathematically correct when using rectified photographs and they eliminate relief displacement in high buildings. Furthermore their stereoscopes give an excellent image.

For plotting of hilly and mountainous terrain we need for the scales 1:50,000 and 1:25,000 instruments of a moderate price with an excellent optical system, giving the highest possible resolving power with a precision which is adapted to a C-factor of the entire procedure of at least 1000 and can be handled by one operator-draftsman. We mentioned the so-called topographic plotters in Par. 3.d. which fulfill these conditions. We mention also the U.S. Balplex plotters and the Kelsh type which for this task are popular in the U.S.A. These instruments should be used with 3 projectors which reduce the time for absolute orientation and improve precision.

In some countries the expensive precision plotters and even universal precision plotters are used for the production of these topographic maps. Only a small contour line interval can justify the application of these high precision but also costly instruments.

It is obvious that for all topographic mapping in scales smaller than 1:5000 a thorough knowledge of geomorphology is of the utmost importance. The photogrammetric operator should not only be trained in photogrammetric restitution procedures but he should also be a real topographer with a fair knowledge of what must be represented in the map and why.

d). Field reconnaissance.

This kind of maps need a field survey for completion of the plotted manuscript. The best method is to have this done by the man who carried out the topographic photo interpretation, either the operator or a special topographer.

In several countries there exist rather detailed instructions for these field completion surveys, adapted to the required representation of the terrain on the final map. We recommend the study of the Topographic Instructions of the U.S. Geological Survey which give a good example.

## Par. 5. Production of large-scale topographic and cadastral maps.

### 1. General remarks.

As explained before the basic difference between this kind of mapping and that mentioned in the previous paragraphs is that we have in general a much greater enlargement from photograph to map, in some cases up to 10 times and even more. The consequence of this is that more precise plotting instruments are used, although specially in this kind of mapping some variety of precision is possible. There are large-scale maps for which the space for project work on the map is more important than its linear precision. In that case the requirements for plotting will be much lower than for a precise map of a legal cadastral administration. The consequence is that in such cases different types of equipment can be used. Therefore we find that for many engineering projects maps are produced in Kelsh type instruments. The direct enlargement from photograph to map is in this case 1:5 and greater enlargement can only be obtained by means of a pantograph which, however, means loss of precision. It is the task of the staff of a cartographic organization to find out which method and equipment is, also economically best suited to the requirement of the wide variety of large-scale mapping projects. As it is not the aim of this paper to deal with the explanation of technical problems, we will limit ourselves to the remark that a great many of these cartographic problems for technical purposes in scales 1:5,000 to 1:2,000 and even 1:1,000 are basically the same as for topographic maps 1:25,000 and 1:10,000. The same kind of wide-angle cameras will be used and for plotting there is a choice between precision plotters, Kelsh type instruments. In some cases, even the new kind of topographic plotters can be recommended, although there the enlargement by means of a pantograph is reduced to only 5 times. Whether aerial triangulation can be applied depends also on the required precision and on the circumstances and cost of ground survey. With the use of the figures indicated in par. 2 each service can determine for itself which would be the best solution.

Because of the great importance of the subject we believe that it is more worth while to discuss in this paragraph one special question viz. that of the survey for land registration and cadastral administration, which is a great problem of almost all less developed countries. The author admits that here he repeats what he has published at other occasions, but he believes it justified because of the necessity to indicate solutions which can simplify this problem.

### 2. Application of air photography to Cadastral Surveys.

Photogrammetry can be used for the production of new cadastral maps in unmapped areas or to replace old maps. We must distinguish between different systems, such as legal and tax cadastre and furthermore, in a legal cadastre, between numerical and graphical systems. In this section we will deal with legal systems these making the highest requirements for precision and reliability. We exclude, however, terrain of class I, built up areas, as there photogrammetry cannot replace ground survey methods.

In almost all less developed countries a good graphical method will be entirely sufficient, on condition that the scale of the maps is in accordance with the size of the parcels.

Notwithstanding the good quality which can be obtained with precision plotting instruments, these plotters have only in a few cases been installed for cadastral surveys in countries where a new survey is desirable. The reason is perhaps that with three 6-hour shifts a day for maps in scale 1:2,000, the yearly production will be no more than about 175 - 250 sq.km per year. Such figures show that in many countries with unsatisfactory cadastral systems, the acceptance of high precision photogrammetric mapping procedures cannot solve their problems within a reasonable time and with a reasonable investment in photogrammetric equipment.

The author believes that in these countries a gradually developing photogrammetric cadastral survey would be the best solution. He strongly recommends to accept such a system, based on the fact, that a high quality airphotograph, on which all artificial boundaries are made visible by signalizing the boundary corners before photography, can be considered as a document. The requirements for a cadastral survey are first of all a reliable description of the boundaries as they were at the moment the parcel was established in agreement between the adjacent proprietors. The second condition is that it should be possible at any time to reconstruct these boundaries in the field with a precision, in accordance with the value of the land. These conditions can be fulfilled by the air photographs as such provided that the photographs are taken after delimitation of the boundaries and the signalization of all artificial boundaries have been carried out.

Measuring two perpendicular lines on each photograph between identifiable points enables the surveyor to rectify these photographs to a prescribed scale as for instance 1:2,000. Drawing white lines between the corners of the parcels makes of each enlarged photograph the basic material for a cadastral sheet on which the numbering of the parcels and other administrative operations can be carried out. Many cadastral surveyors have objections to this simple method, but the advantage is that it gives the less developed countries the only chance to produce within an acceptable delay a reasonable system of cadastral documents. A further advantage is that if at any time disputes arise, or further development takes place, it will be possible to put the diapositives of the original negatives in a precise plotting instrument and produce either a map or read coordinates in the machine and obtain the precision of a numerical procedure.

An objection may be that all these enlarged photographs are loose sheets independent of each other. Cadastral authorities in less developed areas should realize, however, that also the European countries have started with island maps without any geometrical relation between the various municipalities of a country. Therefore it may be that the second stage of development would be to create a geometrical network between the various photographs. This can be done either by ground survey or by means of aerial triangulation and a limited quantity of ground survey. This latter procedure is cheaper and as has been proved in a few countries, gives sufficient precision.

Another disadvantage of the proposed method is the requirements of organization. Among these the main point is that in the country an airplane must be continuously available, because the preparation of the terrain with delimitation and signalization of boundaries can only be carried out for areas of limited size which must be treated one after the other. A second difficulty is the signalization, which in some countries can only be carried out with very primitive material. This should preferably be done at the responsibility of the owners, otherwise the marks will be destroyed or they disappear before the photographs are taken. This, too, is a reason to treat not more than a few thousand acres at the same time.

Par. 6. Base maps for the survey of natural resources.

In the following list the scales of the maps which are most suitable for the representation of natural resources phenomena are indicated. These should be printed on topographic maps of the same scale this giving by far the best and the cheapest solution.

In many of the less developed areas these maps will not exist everywhere. In such cases coordination between the activity of a topographic service responsible for the production of these base maps and the services responsible for the natural resources survey will be highly desirable. It is a bad solution if the last service first produces a base map with very primitive means and a few years later the topographic service comes and makes the final topographic map. Under such circumstances it is for the natural resources surveyor nearly always sufficient to start with photomaps and even uncontrolled photo-mosaics, to which the findings of his natural resources survey can be transferred and reproduced photographically.

1) Geology etc.

1: 25,000 for specific projects (mining, detailed hydrology etc.)
1:100,000 for all geological, hydrological and geomorphological maps
1:250,000 for more remote areas of a country
1:500,000 and smaller for geological reconnaissance maps of large areas.

2) Agricultural purposes, soils, etc.

1: 20,000 for specific projects of intensive irrigation on relatively small surface areas
1: 50,000 for semi-detailed soils maps and soils maps of sample areas
1:250,000 for soils maps which give a review of soils condition of a whole country
1:500,000 and smaller: reconnaissance maps

3) Forestry and vegetation.

1: 10,000 - 1: 20,000 for forest exploitation
1: 50,000 - 1: 100,000 for forestry maps to represent a forest inventory survey
1:500,000 - 1:1,000,000 for overall vegetation maps of large areas

4) Various subjects for land tenure and rural cadastral administrations.

Maps of scales from 1:5,000 to 1:20,000 will be needed.
For surface transportation the same scale can be used.
For road construction in non-urban areas base maps of 1:50,000 will be sufficient.

Par. 7. Modern tools in less developed areas.

About this subject some remarks were promised in the introductory paragraph No. 1. They are essential as aerial survey at present is in that stage of development, where also electronics and modern tools become increasingly important. The time around 1960 can be considered as a kind of landmark in the history of photogrammetry.

Regarding air photography not only new super wide-angle lenses, but also instruments like airborne profile recorders for the determination of height and other electronic equipment for the determination of the position of the camera in the air are used. The electronic dodging printer is recommended by many organizations, in particular those selling such equipment. With respect to restitution instruments we see first of all the automatic recording of the machine coordinates in the stereocomparator as well as in classical analogue restitution machines. The high speed computer is a challenge to many survey organizations. The automation as a kind of final stage is an attractive subject on all photogrammetric congresses and at an exhibition you can always find a crowd of interested observers around such an instrument.

Not only electronics, but even more simple devices are introduced to facilitate the operation of instruments. The connections between the handwheels of an instrument and the pencil on the drawing table are in many cases made nowadays by means of servo-motors. The setting of the orientation elements in the past only by a simple motion of a screw, driven by means of a handwheel or knob, has also become the subject of a so-called simplification by means of servo-motors.

Seemingly, the development in the design of instruments goes in this direction, with the danger that a cartographic service, which wants to be up-to-date believes that without these tools it will be considered as old-fashioned. The author, being responsible for a very large

collection of photogrammetric instruments, which is as much as possible kept up-to-date gained some experience with electronics and those so-called simplifications. This gives him the right and at the same time imposes the duty on him to give a warning to all those, responsible for the purchase of aerial survey equipment , to be in this respect careful and rather conservative. In the less developed areas the proportion between wages and capital investment in modern tools is such that automation and several other instruments with the aim to speed up production, can not be recommended from the economic point of view. This may be different in countries with a shortage of labour, but this does not exist in less developed countries provided an adequate training programme for all ranks has been organized.

The second argument against a step towards electronic and automatic registration, computation, etc. is that in many cases it means the replacement of personnel which can be trained easily, by personnel, for whom the training is much more difficult and takes more time. In a cartographic service which wishes to use an electronic dodging printer and even no more than one instrument with automatic registration of coordinates, it will be necessary to have an electronic engineer at hand at any moment, because both these instruments will be entirely useless if the electronics fail. It is the experience of the author that this happens regularly. In particular the challenge to use dodging printers brought more than one service into difficulties. If there is no possibility for servicing such instruments on the spot, it is irresponsible to start with this kind of equipment and rely on mechanics, who live several thousands of miles away. To give an example, there exists one universal stereoplotter with an excellent mechanical coordinate printer, which never fails. The same instrument can also be delivered with an electronic automatic coordinate printer. In that case the mechanical coordinate printer disappears. To chose the modern solution would, in less developed areas, be a dangerous step which I would never recommend.

There exist a great number of fully reliable, classical instruments which can be used for aerial triangulation and plotting. A triangulation can be computed by desk machines, just as this has been done in many of the industrialized countries and in the author's office since the last 25 years. Why should a service take the risk of electronic tools which definitely will break down from time to time and try to skip a phase of development? The conclusion is that such modern tools can be introduced in cartographic services only if the entire level of development in science and techniques of a country not only depends on a few specialized people trained abroad, but has a broad foundation in the education of the people as a whole.

232 E - Oct. 1962 - 1, 500